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IMPROVEMENT OF SMALL ARMS POINTING FIRE

USING BRACKETING SIGHTS: A FIELD EXPERIMENT PROGRAM

by

James K. Arima

November 1974

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral Isham Linder
Superintendent

Jack R. Borsting
Provost

Prepared by:

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There exists a need to increase the effectiveness and safety of quick-reaction, small-arms fire at short ranges in both military and civilian applications. Rapid target acquisition was identified as a key factor. A circular bracketing sight was designed to accomplish this. Used on an M16A1 rifle fired in the semiautomatic mode, firing with the bracketing sights resulted in maximum improvements over the standard, Army, quick-fire technique of 31 percent with stationary targets and 275 percent with

moving targets at a range of 50 yds (45.72 m.). The more difficult the firing task became, the greater was the differential between standard quick-fire with unmodified sights and the quick-fire with the bracketing sight. The findings have implications for weapons design, training, and other applications of the bracketing-sight concept.

PREFACE

This report brings together in one source the details to date of a program at the Naval Postgraduate School (NPS) to improve the effectiveness of small arms fire at short ranges when quick reaction is required. The program encompasses both developmental and field-testing activities. This particular type of fire has been referred to as pointing fire and quick fire. The need to improve this type of fire was brought to the attention of the author at the ARPA Summer Conference on Small Arms held at the Stanford Research Institute in 1970. There, as documented in the report on the conference, the author conceived the idea of a sight to bracket the target, rather than aligning a weapon on the target, as the means to improve pointing fire.

Such a sight was subsequently created with the participation of Captain William G. Kemple, USMC, a student in the Operations Analysis Curriculum, and Mr. Kenneth Mothersell, shop manager of the Mechanical Engineering Laboratory, NPS. Captain Kemple determined what the general dimensions and configuration of bracketing sights of two sizes should be for the M16A1 rifle. Mr. Mothersell designed and made the prototype. Captain Kemple, with the help of Lieutenant John W. McKinney, USN, conducted the first field test of the bracketing-sight concept as their dual-master's thesis project. The experiment was made possible by the help and cooperation of the U.S. Army Combat Developments Experimentation Command (USACDEC), Fort Ord, California. Major F. A. Isgrig, MSC, the center's human factors officer, was especially helpful, not only for his aid in obtaining the logistic resources necessary for the experiment, but for his ideas in formulating, preparing for, and conducting the experiment. The weapons, ammunition, range personnel, and experimental subjects were provided by USACDEC. The

range, targets, and target mechanisms were provided by the Infantry Training Center, Fort Ord. The instrumentation package was designed and created by Mr. Paul Sparks, laboratory technician in the Man-Machine Systems Design Laboratory, NPS. A detailed report of this stationary target experiment is given in the thesis by Captain Kemple and Lieutenant McKinney (1971).

The second field test of the bracketing-sight concept was conducted by Captain George A. Fisher, Jr., Infantry, and Captain Frank R. McLeskey, Signal Corps, of the U.S. Army as their dual-thesis project in the Operations Analysis Curriculum. A full report of the experiment is contained in their thesis (Fisher and McLeskey, 1972). This experiment was conducted against a moving personnel target on USACDEC's moving-target range at the Hunter-Ligget Military Reservation, Jolon, California. Again, the test could not have been conducted without the superb support provided by USACDEC. This support included the sophisticated range and target mechanisms, range instrumentation, technical support personnel, range personnel, experimental subjects, weapons, and ammunition.

A third field test was conducted by Major Robert A. Miller, Infantry, U.S. Army. The bracketing sight was used to fire the M16A1 from a moving vehicle--a jeep with a mock-up of a MICV (mechanized infantry combat vehicle) firing port. The results of this experiment are not reported here, since they pertained more to the problem of firing from a moving vehicle rather than the sights, themselves. Owing to several factors--the most important of which were the inherent instability of the jeep and the extremely bad weather that caused the firing track to deteriorate markedly--short-burst, automatic fire was required and yet, the overall hit percent was too low to provide any statistically reliable evaluation of the bracketing-sight concept. The small bracketing

sight did score the most hits, and it was preferred by the test subjects. Details of the experiment can be found in Major Miller's (1973) thesis. The test was conducted at Fort Ord, which provided the range facilities. All other resources were, again, provided by USACDEC.

The development and test program was then shifted to the riot gun (shotgun) for two reasons. Since, almost by definition, use of the riot gun involves pointing and quick fire, it was felt that the bracketing-sight concept should help in this case, too, to increase the effectiveness of fire. It was also appropriate to study the riot gun in the context of the previous experiments with the bracketing sight on rifles, since it has often been the weapon of choice for patrols or the point in jungle warfare. Another, and equally important reason for going to the riot gun was the growing appreciation of a need for nonlethal weapons in law-enforcement and the control of civil disturbances. One aspect of this need, as brought out in a conference sponsored by the National Research Council, was to make existing weapons less lethal. Obviously, the riot gun was a prime candidate. While other researchers have sought ammunition changes to accomplish this, it seemed quite possible to reduce unwanted and inadvertent casualties by providing the firer a bracketing sight that would show him all persons in the cone of fire. Results of this program, conducted with Captain Richard D. Read, Signal Corps, U.S. Army, will be reported later.

Finally, the author wishes to express his deep appreciation for the work done by these marvelous officers who have taken part in the program. Their enthusiasm, great effort, and professional skill--in both their military and academic fields--were inspirational. While a great amount of help was provided, especially by USACDEC, the experiments mentioned above were actually conducted

on a "shoestring" basis with respect to the personnel and manhours actually expended on the experiments. That is, one or two officers--with their thesis adviser--designed, fielded, and analyzed complex livefire tests that normally would require a team of military personnel and their scientific counterparts working over a considerable period of time. These facts would seem to lend strong vindication to a program of graduate education for military officers that gives them the opportunity to act in such capacities. Attention should be called to the fact that officers from three different services--U.S. Marine Corps, U.S. Navy, and the U.S. Army have participated in the program. This could not have taken place at any other institution of advanced learning. It demonstrates the unique role of the Naval Postgraduate School in providing quality education to military officers that is relevant to their future careers. It is indeed exciting and always challenging to be a part of this picture. Additionally, this development and testing program should provide valuable information to the civilian as well as the military community.

J.K.A.
10 November 1974

IMPROVEMENT OF SMALL ARMS POINTING FIRE USING BRACKETING SIGHTS:

A FIELD EXPERIMENT PROGRAM

BRIEF

The problem investigated was to improve the effectiveness and hit probabilities of small arms fire at short range using pointing fire. A bracketing sight was designed and evaluated in a program of four field experiments. Two of the experiments are reported in detail. The need to improve quick reaction, short-range fire has been amply demonstrated in many military settings, but particularly in jungle warfare. A similar need has been demonstrated in civil law enforcement. In the latter case, there is also the requirement to make fire as discrete as possible to prevent unwanted casualties. An activity analysis of this type of fire suggested that a sight that would aid the firer in quickly acquiring his target might improve the accuracy and quickness of fire. A circular sight that would bracket the target was designed and mounted on the front sight of an M16A1 rifle. A large and small sight were designed since it was not known what size would be optimum. In a stationary target experiment, 10 trained riflemen fired single shot at pop-up targets that appeared for 1.6 secs. at ranges of 25 and 50 yds. They used weapons with the standard sight (control) and the two bracketing sights. Significant effects were found for sights ($p < .05$) and for ranges ($p < .001$). The small bracketing sight was found to be better than the other two. It was better by 31 percent at 50 yds. and 19 percent at 25 yds. when compared with the standard sight using Army quick-fire doctrine. In a field experiment using moving targets, 12 trained riflemen fired at a popup silhouette target that appeared for 2.5 secs. while moving laterally at 6 mph. at ranges of 25 and

50 yds. The three sight conditions were as before. The small and large bracketing sights were significantly better than the control sight ($p < .001$). While the two bracketing sights did not differ statistically, the larger bracketing sight achieved the most hits and was better by 118 percent at 25 yds. and by 275 percent at 50 yds. over the standard sight. The results showed that a sight aid, such as the bracketing sights, could improve short-range, quick fire markedly. The degree of improvement was greater as the task became more difficult. Since the bracketing sight was easy to use, it should be an aid in training. There remained the problems of determining the optimum size and the size requirements when fire with greater dispersion is used, such as with automatic fire and fire with the riot shotgun.

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1. INTRODUCTION AND OBJECTIVES.

The need to use small arms effectively and quickly at short ranges has grown rapidly in recent years. This need was dramatically emphasized in the wars in Southeast Asia where face-to-face military encounters frequently took place at ranges under 50 m. because of the dense foliage in the region and the tactics that emphasized infiltration, surprise, and ambush. The need to employ small arms in this fashion, along with similar tactics, has also appeared in many nonmilitary contexts and, often, just as dramatically. These have included civil disturbances, highjackings, armed crimes, and prison revolts.

The use of small arms in the civil sector has had an added dimension. There is the very grave requirement to prevent unwanted casualties. This requirement makes the situation very difficult because there is a positive relationship between the dispersion pattern of fire and the ability to hit a point target. The military user of small arms can optimize what is, essentially, a built-in error in his system to ensure a higher probability of hitting the target. The law-enforcement user, on the other hand, must employ very discrete fire, and he cannot make indiscriminate use of dispersion in aimed fire to attain the desired target hits.

A source of problems that is common to both the military and civilian user of small arms is the fact that they have not been designed for the short-range, quick fire role. This role frequently requires that the weapon be pointed, rather than aimed. But weapons have been designed for the hunter, soldier, and marksman who uses deliberate, aimed fire. Accordingly, real differences can be demonstrated in the effectiveness of pointing fire by simple changes to existing designs (Kramer and Torre, 1964). The small-arms user has been disinclined to use such modifications for a variety of reasons,

among which are those of impracticality, expense, and a fear of degrading aimed fire as a result of the modifications. But probably, the greatest impediment to change in the systems lies in the nature of those who are experts in the design and use of small arms. They feel very reluctant to give up the many years of craftsmanship, skill, and tradition that have gone into the design and fabrication of weapons and the modes of fire that are used in keenly fought, competitive situations.

One answer attempted by the U.S. Army and Marine Corps to the problem of attaining effective, quick, pointing fire was a deliberate attempt to develop skill in pointing fire. They based their training on the skills exhibited by trick-shot experts and the recommendations of these extremely skillful firers. Originally termed "quick kill," but later changed to the "quick fire" method, the emphasis was placed on firing with both eyes open, not using the sights, looking well over the top of the sights, and pointing the rifle. Air rifles, highly miniaturized targets, and hand-thrown discs were incorporated into the training program. The program had considerable face validity and a good sales effort, but very little hard evidence as to its effectiveness for the individual soldier.

The objective of the research reported in this paper was to enhance the effectiveness of pointing fire. The approach to this objective used three steps: (1) an analysis of the quick-fire situation with a human activity orientation, (2) derivation of solutions to the man-weapon problems identified, and (3) field tests of the proposed solutions.

2. ANALYSIS OF SHORT-RANGE, QUICK-FIRE SITUATIONS.

2.1. Situational Demands.

In the extreme, although not uncommon, case the quick-fire situation is one in which the firer is faced with a kill or be-killed situation. Another type of situation requires the firer to shoot in a very short, discrete time period or "window." The situation might be considered as one of "hit fast or miss your opportunity." In the civil context, such situations might arise when there is a need to surprise the intended target or when the target person momentarily relaxes his vigil over his hostage. A very discrete, psychological time period might be involved when one fires in a civil disturbance to frighten or warn the group to be controlled. Generally, then, the short-range, quick-fire situation places a very high demand on the time to the first hit. As previously stated, the range is short, the target is another individual, and, in the civil context, there should be no unintended victims.

2.2. Psychological Factors.

2.2.1. Visual Factors.

The demands of the short-range, quick-fire situation are reflected in the firer, first and foremost, by his need to maintain constant visual contact with the threat. This, in turn, will be reflected behaviorally in the firer by his keeping both eyes open and maintaining visual focus at infinity. Keeping both eyes open means that he will be pointing his weapon binocularly. Truly binocular pointing (sighting) only occurs, however, when the individual's point of reference is equidistant between his two eyes. That is, he should be using his so-called "Cyclops" eye. Unfortunately, the experimental literature is quite equivocal as to whether individuals ever use the Cyclops eye or, if they do, under what circumstances. For example, it may well be that a well-

trained individual is using his Cyclops eye when he fires a revolver using two hands, two eyes, and facing his target squarely. In this example, the firer's focus is on the target and the weapon is placed directly in line with the Cyclops eye. If he were to close his right eye, he would notice that the revolver is aimed to the right of the target. If he were to close his left eye, the aiming point of the revolver would jump a similar distance to the left of the target.

With a longer barrel and stock, characteristic of rifles and other shoulder-fired weapons, it is not practical to fire in such a manner. As a result, the weapon is brought to the right or left shoulder and normally sighted with the right or left eye. Many trained marksmen fire with both eyes open while sighting with one eye. But in this case, they are making use of the sights provided on the weapon. When a person is told to look over the top of the sights and point the weapon instead of aiming it, he may be using his right or left eye or he may be using his Cyclops eye to align the weapon with the target. The infantry training literature was cognizant of these possibilities and provided instructions to the trainer for determining the dominant eye of the firer when he was consistently biased in his aiming point. Presumably, his dominant eye took over the sighting when he fired with both eyes open. If the dominant eye was opposite to the side he was firing from, the bias resulted. For example, if the shot-group center tended to occur to the left of the target when firing right-handed with both eyes open, the person's left eye was said to be doing the sighting. Accordingly, there is the possibility of a sighting dominance conflict when firing with both eyes open in a stressful situation. The modifications previously referred to to make military rifles better pointing weapons included such devices as a sighting

bar connecting the front and rear sights to facilitate alignment of the weapon with the target.

If the individual maintains his focus at infinity in the quick-fire situation because he needs to maintain continuous visual surveillance of his target, it is obvious that he cannot use the sights on the weapon properly, since they are less than an infinite distance from his eye. This is particularly true of the rear sight. Accordingly, the several newer sights under development that require the firer to use a rear sight or look at an objective field near his sighting eye will not aid him in the quick-fire situation. There is also another reason why sights near the eye cannot be used in this situation. The reason is this: It has been found and confirmed in many experiments that the pupillary reflex is responsive to psychological as well as light stimulation. When a person is highly aroused or excited, his pupils will open widely. No doubt, this reflex had survival value in that letting in large amounts of light to the eye ensured that danger signals in the environment would not pass unnoticed. Unfortunately, near focus is severely degraded when the pupils are enlarged. Anyone who has had eyes bathed in atropine for ophthalmologic examination will immediately attest to this phenomenon. So here is another reason why conventional or some developmental sights will not aid much in the quick fire situation. The general conclusion to be made in this area of analysis is that sights which require a near focus of the eyes will not be of use to an individual in the quick-fire situation. While this may or may not be the original basis, the quick-fire principle of not using the sights but looking over the top of them appears to be justified for current weapons.

2.2.2. Perceptual-Motor Factors.

When time to the first hit is of paramount importance, very rapid acquisition of the target is a necessity. If the weapon is already at the shoulder, it must be slewed to where it is pointing at the target. If the weapon is held at port arms, bringing the weapon to the shoulder and pointing it at the target may be accomplished in a more-or-less, single movement. However, final adjustment using a smaller slewing movement will be required to acquire the target properly. Thus, taking the shoulder as a point of reference, the muzzle end of the weapon must be slewed to where it is pointing directly at the target. This, then, is the simple, but all-important process of target acquisition in the quick-fire situation.

As simple as the movement may be, closer examination reveals some complicating factors. First, it is not often realized that the target in quick-fire situations is very large when compared against the built-in accuracy of the weapon and the aiming accuracy that is possible for the operator of the weapon. At 200 m. on a known-distance range, the root mean square (RMS) error of a group of firers will be less than 1 mil, even when relatively inexperienced firers are used (Saul and Jaffe, 1955). A very important reason why this is possible is the fact that the bullseye at that range is slightly over 1 mil. With plenty of time, careful aiming, and gentle "squeezing off" of the rounds, it is possible to place many shots within the bull itself. On the other hand, taking a man to be 50 cm. wide when viewed head on, he will present a target that is 10 mils wide at 50 m. and 20 mils wide at 25 m. Even with the requirement for speed of fire, why is it so difficult to hit such a large target at short ranges?

The answer apparently lies in the fact that the weapon, its sights, and the training doctrine are optimized for discrete, small, aiming points. Thus, the larger and more amorphous a target becomes, the larger will be the aiming error of the firer. Stated in another way, the basic concept in acquiring a target is to align the weapon with a very small, distinct point. This, of course, is incorporated in the doctrine of obtaining a proper sight picture when firing. This doctrine is not only useless, but it may even become a hazard in the quick-fire situation if the firer tries to apply it unconsciously. This may occur in two ways. First, he may lose some precious time in searching for an aiming point within this large target. Second, he may not find a point at which to aim with the result that he shoots more-or-less randomly in the general direction of the target. Here again, these factors could be cited to justify the quick-fire doctrine of not using the sights and looking over the top of them.

2.3. Performance Trends.

The results of three field experiments provide empirical verification of the ideas expressed in paragraph 2.2., above. The first experiment by Sterne and Yudowitch (1955) used one team of seven "proficient" shooters and another team of seven "regular" shooters who had just completed basic training. They fired as a team at a row of seven pop-up targets that appeared individually at random intervals for a constant period of time. The exposure times were varied during the course of the experiment, but they were constant, announced, and demonstrated before a particular firing run. The row of targets was 40 yards (36.58 m.) from the firing line. The targets were circular (28 in. in diameter)(71.12 cm.) with a black bullseye in the center. Each member of the team fired exactly one round at each target as it appeared in view. He used conventional sighting doctrine and fired from a standing position.

The other two experiments (Kramer and Torre, 1964; Torre, et al., 1964) were quite similar to each other and conducted by the U.S. Army Human Engineering Laboratories (HEL). Silhouette targets were placed at three ranges, and they appeared individually at random intervals for approximately 2-3 secs. The ranges in the Kramer and Torre experiment were 20, 40, and 60 meters; those in the Torre, et al. experiment were 40, 60, and 80 meters. Infantry soldiers were used as subjects. They were instructed to use pointing fire and to fire as rapidly as they could. The Sterne and Yudowitch experiment used the M1 rifle and the M14 carbine. The Kramer and Torre experiment used the M14 carbine (for the data reported here), and the Torre, et al. experiment used the Stoner rifle with ball ammunition (for the data reported here). Only data from semiautomatic fire are used here.

One comparison that is meaningful is that at 40 yards or 40 m. in these experiments, since the ranges are comparable. Using the trials for both proficient and regular shooters and combining the M1 and M14 results, an aiming error (RMS) of 3.3 mils was obtained for the Sterne and Yudowitch experiment when the targets appeared for 8 sec. On the other hand, aiming errors were 13.3 and 15.0 mils for the M14 and Stoner weapons, respectively, in the other two experiments, where the target exposure time was approximately 2 sec. While the conditions were quite different between the Sterne and Yudowitch and the HEL experiments, the results are unambiguous. Under more ideal conditions--aimed fire with ample time to fire and circular targets with bullseyes--the aiming error is less by a factor of 4. The aiming error in the Sterne and Yudowitch experiment at a target-presentation time of 2 sec. (comparable to the HEL experiments) was 7.5 mils, which is about half of that of the HEL experiments. When the Sterne and Yudowitch results at 2 sec. are examined in

more detail, they show (for the M14 carbine only) that the error was 3.5 mils for the proficient firers and 16.2 mils for the "regulars." The difference can be attributed to the fact that, at this target-exposure time, the proficient firers were able to aim their shots, while the regulars were not. All firers agreed that only pointing fire was possible at the 1 sec. exposure period, which was also used in the Sterne and Yudowitch experiment. Finally, combining data from the two experiments where necessary, the HEL experiments showed the aiming error (in mils) to be 14.2 at 20 m., 13.1 at 40 m., 10.4 at 60 m., and 9.3 at 80 m. Thus, for the same target, aiming errors become smaller as the range increases.

The conclusions to be made from these experimental comparisons is that aiming error is small when aimed fire is used. When the target presents a convenient point for its acquisition, such as a bullseye, aimed fire can be used by proficient firers at a target-exposure period as short as 2 sec. under range conditions. Under conditions requiring pointing fire, the dispersion of fire increases greatly and continues to increase as the target becomes larger (or closer).

2.4. Human Requirements.

It is obvious from the preceding analysis that the average soldier needs an appropriate sight and firing doctrine to enable him to improve his quick-fire. The sight should emphasize rapid target acquisition, and not precise aiming. It should enable the firer to keep his eyes on the target while acquiring it in his sights, be far enough away from his eye so that it will be in focus, and it should provide some aid to aiming which is critically missing in the quick-fire technique.

3. DESIGN OF A CIRCULAR, BRACKETING SIGHT.

3.1. General Considerations.

The basic concept in designing an appropriate sight was to reverse the existing arrangement of rifle sights. That is, the rear sight was to be the post and front sight, a relatively large bracket. The reasoning for this arrangement was as follows. The rear peep sight on a military rifle or carbine, for example, serves to limit the visual field severely and provide a frame of reference for centering the front sight. This, in turn, enables the positioning of the front sight on an aiming point so that the weapon is aligned to that point. This permits a very high degree of precision in aiming for the skilled marksman. In principle, it assumes that the target has been acquired or that target acquisition is not a problem--the problem is precise aiming. The reverse arrangement provides a reference or base point at the rear post and the bracket at the far end of the rifle is slewed until it frames the target. When the target and the rear post are in the center of the bracket, it has been fully acquired for firing. What the concept looses in precision, it certainly makes up in the rapidity of acquiring the target, which is the primary requisite in quick fire. The major difference is that with the conventional method, the weapon must be placed on a small point within the target. With the reverse arrangement, the entire target is centered in a relatively large frame. A sight picture is still possible, but it is a completely different sight picture that is especially appropriate for quick fire. In concept, it is like the old press camera that permitted the use of a wire bracket for quickly framing action shots.

Given the concept of a bracketing sight, there were still some general questions to be answered. These concerned, primarily, the shape and size of

the forward bracketing element. With respect to shape, a triangular or diamond-shaped bracket could provide a good aiming aid in that one could draw imaginary cross-hairs from the corners and easily provide a central reference point. But this would stress aiming, and acquisition would not be optimum because the area within the bracketing sight would be small considering the maximum vertical and horizontal dimensions. A U-shaped bracket would be analogous to the square bracket on the press camera, but it would be unwieldy and a poor aid for aiming--i.e. centering the target would be difficult. A circular bracket seemed to be the best because it was efficient with respect to space, it would provide a central reference without stressing conscious aiming, and it would be compatible with the natural visual field, which is circular with a central point of maximum clarity.

With respect to size, the front sight had to be large enough to bracket a typical personnel target at a typical range. The larger the sight, the easier it would be to bring the target into the sight picture but the greater would be the loss in aiming precision. Also, a larger sight would be better for a moving target; a smaller sight, better for a stationary target. The reasoning behind this was that a moving target would be more difficult to acquire in the sight and that once the target was acquired there should be room within the sight to lead it.

Another consideration was the thickness of the material making up the bracket. It had to provide a frame of reference around the target, and yet it could not obstruct a view of the target. The thickness of the material would also make a difference in firing under conditions of limited visibility. That is, it would have to be thicker to be useful under such conditions.

A final consideration was that it would be desirable to have a quick-fire sighting arrangement that would not interfere with or degrade the use of the regular sights for aimed fire. Ideally, the sight configuration would be one that could be folded flat against the muzzle when its use was not anticipated and could be placed into its quick-fire role with a minimum of effort.

3.2. Detailed Specifications.

The M16A1 rifle was selected as the weapon for the design and test of an experimental bracketing sight because of its availability for test firing and because it was known to be a weapon with poor pointing characteristics. Selection of this weapon, with its high rear sight, made the design problem one of creating a circular frame around the front sight. Since it was not feasible to select or analytically calculate an optimum size, circular sights with two diameters were designed. The smaller sight was designed to encompass the breadth of three average men at a distance of 25 yards (22.86 m.), and the larger frame, to encompass six men at that distance. The point of attachment (front sight) was taken to be 18 in. (45.72 cm.) from the eye and a man's width, 20 in. (50.8 cm.). Thus, the sights enclosed an area of 67 mils and 133 mils at 25 yards. The actual diameter of the aperture of the small and large sights was 1.32 in. (3.35 cm.) and 2.64 in. (6.70 cm.), respectively. The width of the ring metal as viewed by the firer was 1/8 in. (3.18 mm.).

The entire bracketing sight, made in three pieces, is shown in Figures 1 and 2 attached to the front sight of the M16A1 rifle. There was a clasp that fitted snugly on the forward upright of the front sight. A bracketing sight mounting piece was then screwed onto the clasp. The mounting piece had a long vertical slit which permitted the vertical adjustment of the bracketing sight using a knurled set screw (Figure 2). The third piece was the bracketing sight,

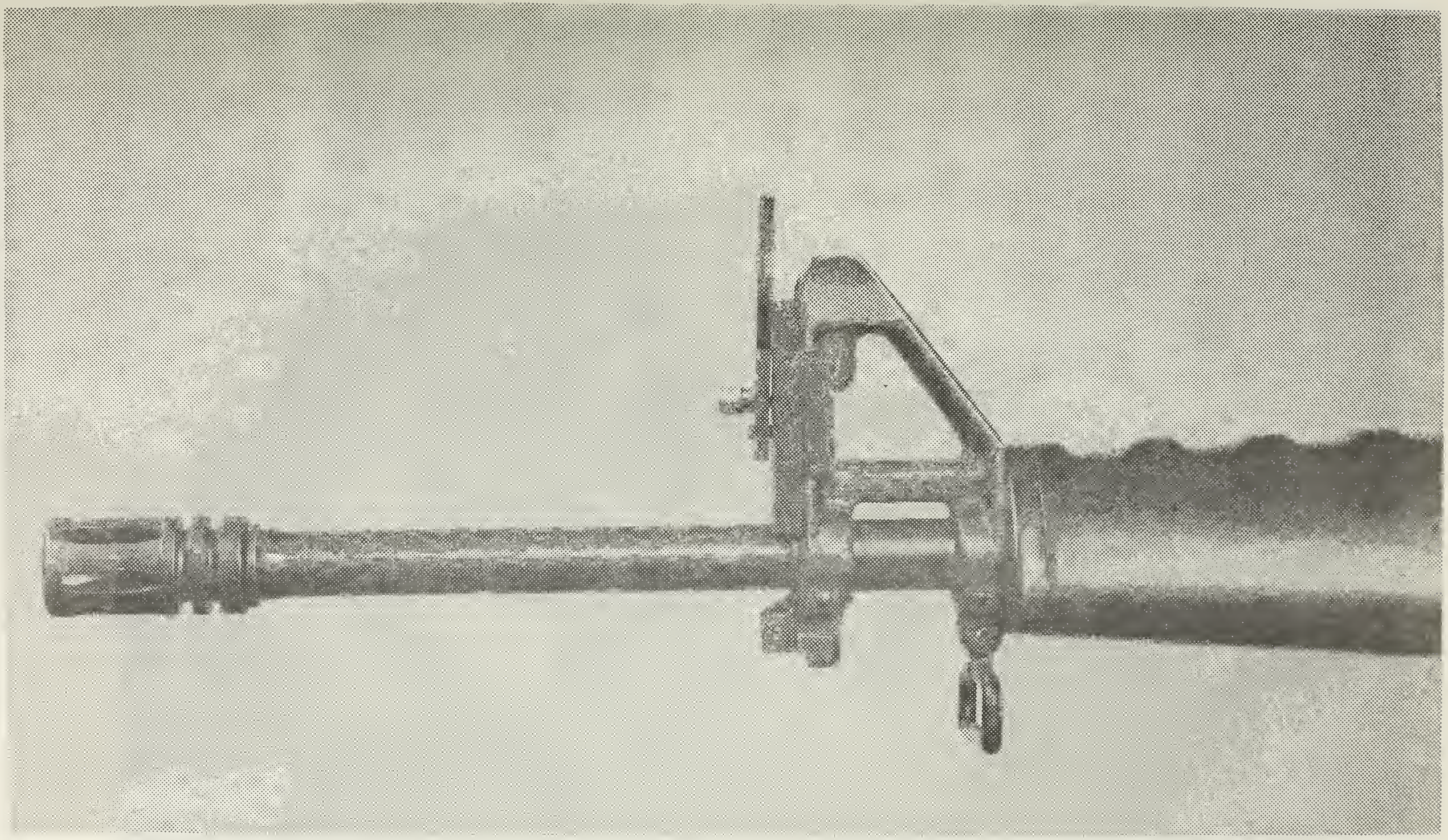

Figure 1. Side View of 1.32" dia. Experimental Bracketing Sight on M16A1 Rifle.

Figure 2. Front View of 1.32" dia. Experimental Bracketing Sight on M16A1 Rifle.

itself, which can be clearly seen in Figure 2. It was affixed to the mounting piece with the aforementioned knurled screw and a pin to prevent rotation of the sight around the adjustable screw. The large bracketing sight was exactly the same as the small sight shown in these figures, except for the diameter of the sight opening, which was twice as large, and is shown in Figure 3. Figure 3 also shows the two countersunk screws by which the mounting piece was attached to the clasp. Figure 4 shows a side view of a soldier with the small bracketing sight in firing position.

3.3. Firing Doctrine with the Bracketing Sights.

The doctrine that was used in the experiments to be described, when firing with the sight-modified M16A1, was as follows. The body position, the manner of bringing the weapon to the shoulder from high port arms and obtaining a firm stock weld, and the instinctive pointing of the weapon were all adopted from the doctrine for the quick-fire technique. The only difference was that the firer was instructed to close one eye and look through the sights until the target was bracketed in the circular frame.

Figure [illegible]. Front View of 2.64" dia Experimental Bracketing Sight on M16A1 Rifle.

Figure 4. Side View of Soldier with Small Circular Sight in Firing Position.

4. EXPERIMENTAL TEST AND EVALUATION.

4.1. Stationary Target Experiment.

4.1.1. Purpose.

The purpose of this experiment was to evaluate the effectiveness of quick-fire against stationary targets utilizing conventional quick-fire doctrine and the large and small bracketing sights. Since this was the first experiment, it was necessary to make the evaluation simple and clear-cut so that attribution of the findings could be unequivocably made to the three firing techniques.

4.1.2. Subjects.

The 10 test subjects (*S*s) were infantry enlisted men from the U.S. Army Combat Developments Command Experimentation Battalion stationed at Fort Ord, California. All *S*s had an infantry military occupational specialty and had received formal quick-fire training in the past. Seven had experience in Vietnam.

4.1.3. Facilities.

The experiment was conducted on the beach ranges at Fort Ord. The range for the experiment was set up between two berms of a known-distance range. The layout of the range is shown in Figure 5. The components of the range were four pop-up targets, a single firing station, and a control station. The four targets were placed so that two were on an arc 25 yards (22.86 m.) and the other two on an arc 50 yards (45.72 m.) from the firing station. The two targets at each range were placed so that they were 10° to the right and left of the firing station--that is, they subtended an angle of 20° for a firer at the firing station. The firing station was on the same level as the targets and was merely marked to show where the firer was to stand. The control station was located on a berm approximately 10 feet (3.048 m.) above the level of the range and the firing station. The area between the berms was flat and level with sparse, low vegetation.

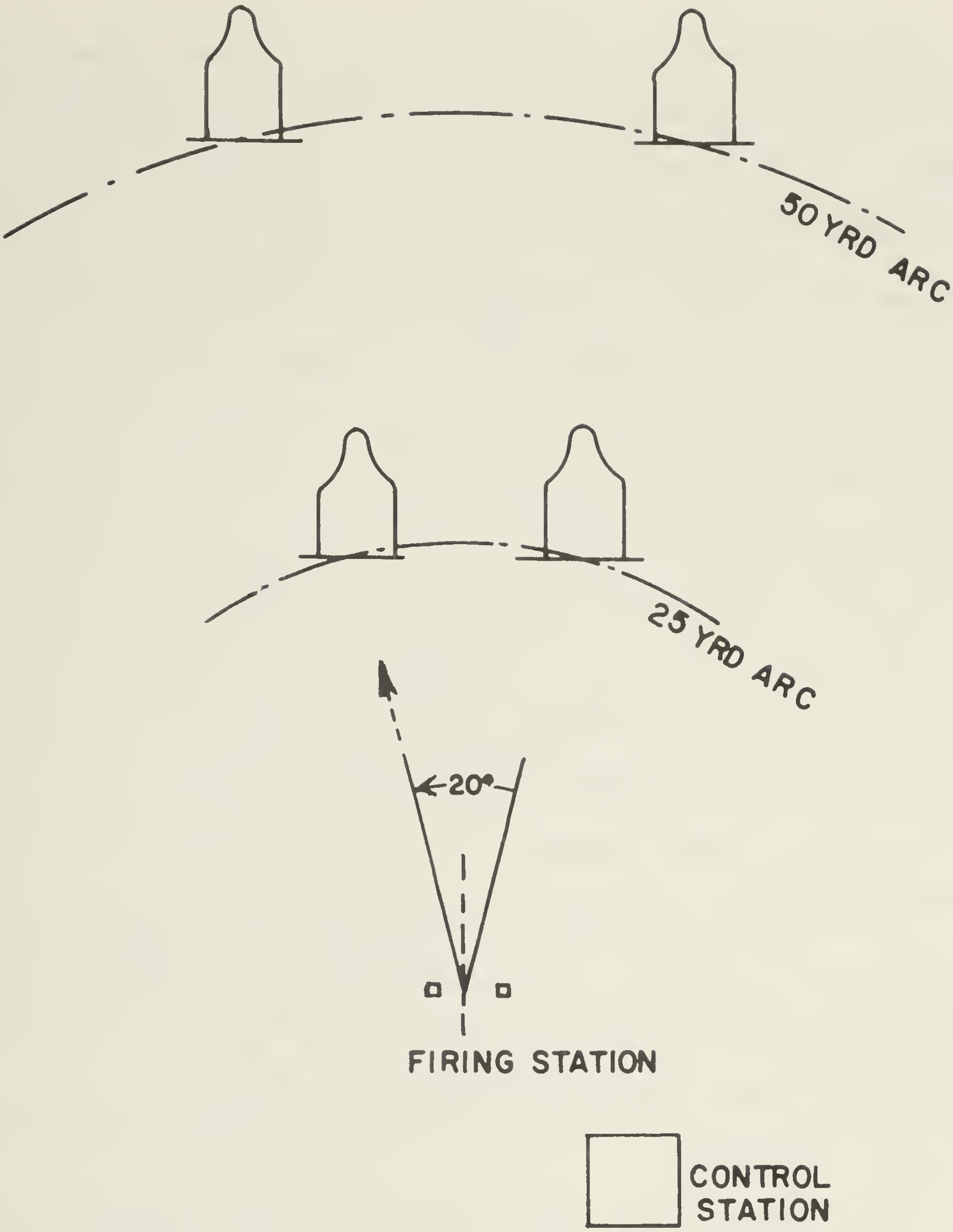

Figure 5. Layout of the Range for the Stationary Target Experiment.

The targets were U.S. Army, E-type, polyethylene silhouettes measuring 40.25 in. (102.235 cm.) high and 19.5 in. (49.53 cm.) in breadth. They were mounted on U.S. Army, target-control mechanisms (M31A1) to provide timed target exposures and to initiate the hit-indicator circuit. The control mechanisms were dug in and sand-bagged which resulted in a masking of about 1 ft. (30.48 cm.) of the lower portion of a target when it was exposed. The sand-bagging also helped to prevent premature cuing of which target was to appear by masking the target completely when it was in the flat position, and it also helped to prevent tardy hits as the target was going down.

A small control console was placed at the control station to permit manual selection of the targets for exposure and to indicate hits on a target by the flashing of two fluorescent bulbs. The command to the target went through an interval timer which raised the selected target for 1.6 seconds.

4.1.4. Experimental Design.

The experimental design was a repeated measures design with each S firing under all conditions. The independent variables were the three weapon configurations (to be referred to as the "sights" variable), two target ranges, two target directions (right and left of the firer), and the 10 Ss.

4.1.5. Procedure.

Prior to actual test firing, the Ss were given approximately two hours of training. A short, refresher lecture was given in the prinicples of quick-fire shooting, followed by brief instructions in the changes in that technique to be employed with the modified sight configurations. The Ss fired five rounds with each sight configuration to familiarize themselves with the proper body-weapon-target alignment and also to permit correction of faulty (nondoctrinal) firing techniques. The training was concluded with a complete training run of the experimental firing conditions.

In the actual test firing, one trial consisted of an _S_ firing 20 shots with one sight configuration at the four targets. Each of the targets appeared 5 times in a random order, with only one appearing at any one time. The interval between target presentations was short but unspecified. The order in which a particular _S_ fired the three sight configurations and the order in which he fired were randomized. Only one shot was fired at a single target presentation. If the _S_ failed to fire, a miss was recorded. The _S_ was informed verbally whether a hit or miss resulted with each shot. The dependent measure was the number of hits scored on each target by each shooter with each sight configuration. Since each of 20 _Ss_ fired 10 shots with each of three sight configurations, there were 600 data points in all. After completion of all firing, the _Ss_ completed a questionnaire soliciting their feelings and preferences about the test firing and the sights.

While the test was simple and formal, the reader should be cognizant of the features that made it a reasonably valid test of quick-fire. There was target uncertainty--that is, the _S_ did not know exactly when or which target would appear. The _S_ was under extreme time stress--the targets just "waved." An additional stress originated from the fact that he fired alone with everyone else watching and within earshot of the hit or miss feedback provided him. There were realistic ranges to the targets based on operational data. The _S_ was firing on flat, natural ground--not from raised berm to targets on another raised berm. He received immediate feedback as to the results of his firing. And the _Ss_ were trained troops who normally used the weapons fired.

4.1.6. Results.

The overall results of the experiment are shown in Table 1. The overall hit rate was 45 percent with a hit rate of 28 percent at 50 yards (45.72 m.)

Sights	Direction		Total	Sights	Direction		Total	Sights	Direction		Total
	Right	Left			Right	Left			Right	Left	
Small	36 (72)	33 (66)	69 (69)	Small	19 (38)	15 (30)	34 (34)	Small	55 (55)	48 (48)	103 (51.5)
Large	35 (70)	23 (46)	58 (58)	Large	12 (24)	13 (26)	25 (25)	Large	47 (47)	36 (36)	83 (41.5)
Standard	34 (68)	24 (48)	58 (58)	Standard	12 (24)	14 (28)	26 (26)	Standard	46 (46)	38 (38)	84 (42.0)
Total	105 (70)	80 (53)	185 (62)	Total	43 (29)	42 (28)	85 (28)	Total	148 (49)	122 (41)	270 (45.0)

(a) 25 Yards (22.86 m.) (b) 50 Yards (45.72 m.) (c) Both Ranges

TABLE 1.

RESULTS OF THE STATIONARY TARGET EXPERIMENT

(Hits, above, and percent hits, below, in parentheses)

and 62 percent at the 25-yard (22.86 m.) range. Over the entire experiment, the small sight attained a 51.5 percent hit rate; the large sight, 41.5 percent; and the standard sight, 42.5 percent. The results were subjected to a four-factorial, randomized block design, analysis of variance. The Ss were considered as blocks, since each S received all combinations of the main variables. (The data were first transformed using the arcsin transformation, since they were in the form of proportions.) The only significant effects were those for sights, $F\ (2, 18) = 4.21$, $p < .05$, and for range, $F\ (1, 9) = 31.80$, $p < .001$. The main effect for direction of fire was not significant. None of the interactions of these variables was significant. A Scheffé multiple comparison test was conducted for the sight variable with the result that the small sight was found to be significantly different from the large bracketing sight or standard sight with no statistically significant difference between the latter two sights.

4.1.7. Discussion.

The results show that the small sight was 23 percent better than the standard, quick-fire procedure over the entire experiment. It was better by 31 percent at 50 yards (45.72 m.) and 19 percent at 25 yards (22.86 m.). Since there was no significant interaction between sights and distance, these differences are all reliable. The bracketing sight can considerably enhance performance in quick-fire situations, but the effect is dependent on the size of the sight opening. The results also show how severe the inverse relation between distance and accuracy is at short ranges and how the bracketing sight can serve to reduce the loss of accuracy with increase in range. These percentage differences between the small bracketing sight and the standard procedure are very large when one considers that differences in the accuracy of small

arms are usually difficult to demonstrate. The questionnaire results showed that the _Ss_ preferred the small sight, with the standard sight second and the large bracketing sight third. All of the _Ss_ thought that the bracketing sight was beneficial, and nine of the ten _Ss_ thought it was a valid concept for improving pointing fire.

4.2. Moving Target Experiment.

4.2.1. Purpose.

The results of the experiment with stationary targets showed that the bracketing sight could enhance pointing fire under the conditions encountered in the experiment. A more challenging test would be the case where the target is moving. Undoubtedly, many targets in the quick-fire environment are moving, so a test of the bracketing-sight principle against moving targets would help to validate the principle for practical use in addition to testing it against the inherent difficulty encountered in moving targets. Several new considerations arise in this situation. It may be that any sight may be detrimental to pointing the weapon at a moving target. Perhaps it is not possible to improve on the shotgun with its uncluttered barrel and only vestigial sighting devices, such as beads. Moving targets, as previously suggested, should require a different aperture size for the bracketing sight because the target is more difficult to acquire and because one may want to lead the target after it has been acquired in the bracket. Another very important consideration is this. The stationary-target experiment suggested that the bracketing sight was more of an aid as shooting became more difficult--i.e. at the greater range. Would this same trend show up against moving targets? Or does the moving target present such a difficult task for the average soldier firing a military small arm that no aid could serve to improve his accuracy? Answers to questions

such as these could only be obtained by a livefire test, such as the experiment to be described.

4.2.2. Subjects.

The Ss were 12 soldiers from the same experimentation battalion of the U.S. Army Combat Developments Experimentation Command (CDEC) stationed at Fort Ord, California, that provided the Ss for the preceding experiment. All had an infantry military occupational specialty and had previously received quick-fire training. They were all right-handed. Only one of this group had experience in Vietnam.

4.2.3. Facilities.

The experiment was conducted on the CDEC moving-target range at the Hunter-Liggett Military Resevation (HLMR), Jolon, California. The range was laid out in a natural, slightly sloping terrain that was clear from the firing positions to the target track but wooded behind. The weather was ideal with the temperature from 50 to 56 degrees (F), essentially no wind, and no precipitation.

The range layout is shown schematically in Figure 6. The components of the range were a target track, four firing points, a moving target, and control and power station. The target track was 150 feet (45.72 m.) of aluminum rails. An engagement area along the target track was determined to limit the range fan. The four firing points were located so that two were at a line 25 yards (22.86 m.) from the target track and another two were 50 yards (45.72 m.) from the track. At each firing line, the two firing positions were designated right and left firing positions. The control and power stations were located a short and safe distance away from the end of the track. A view of the range from the 50 yard (45.72 m.) firing line is shown in Figure 7. Visible in the

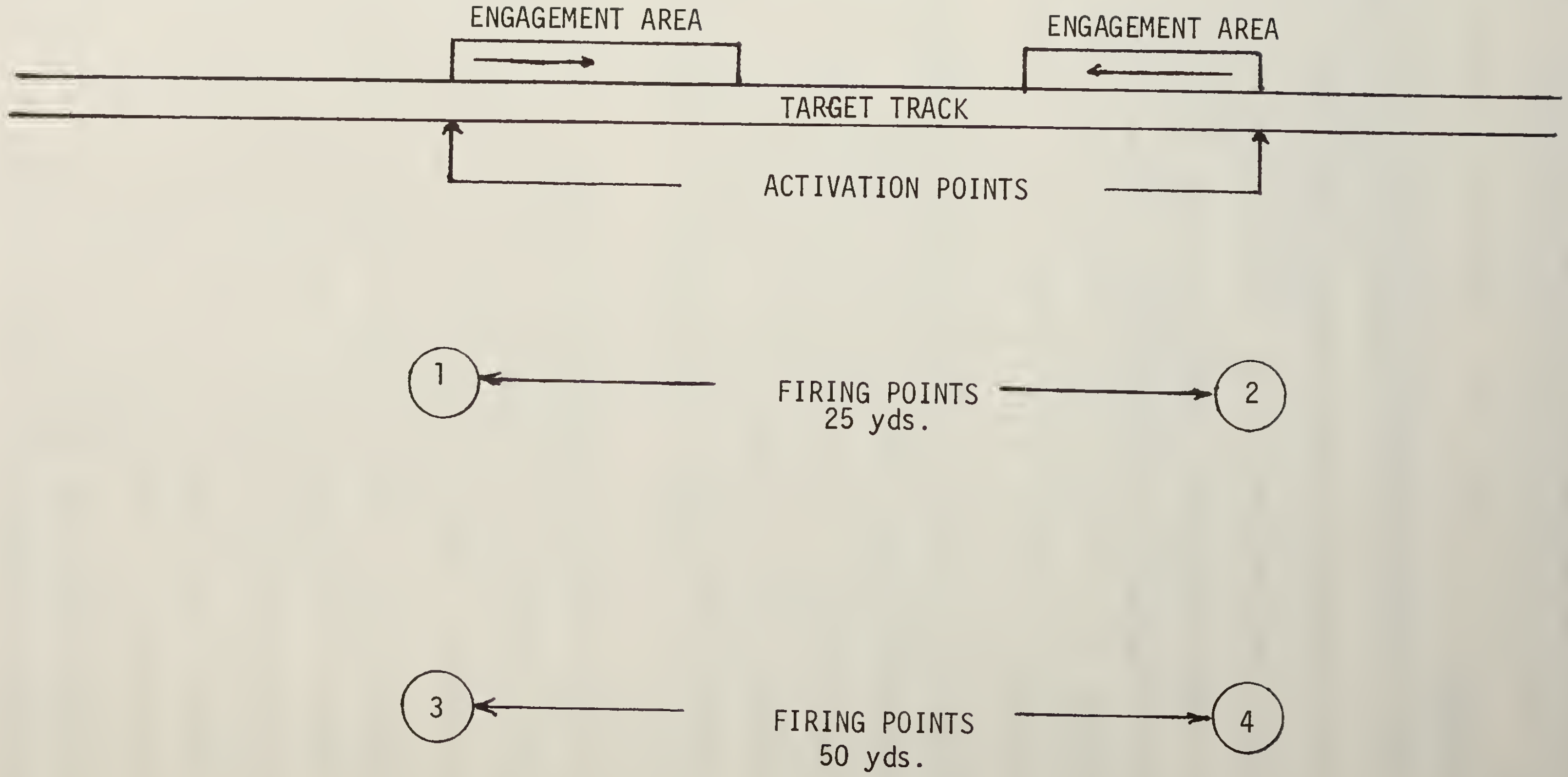

Figure 6. Schematic Layout of the Range for the Moving Target Experiment.

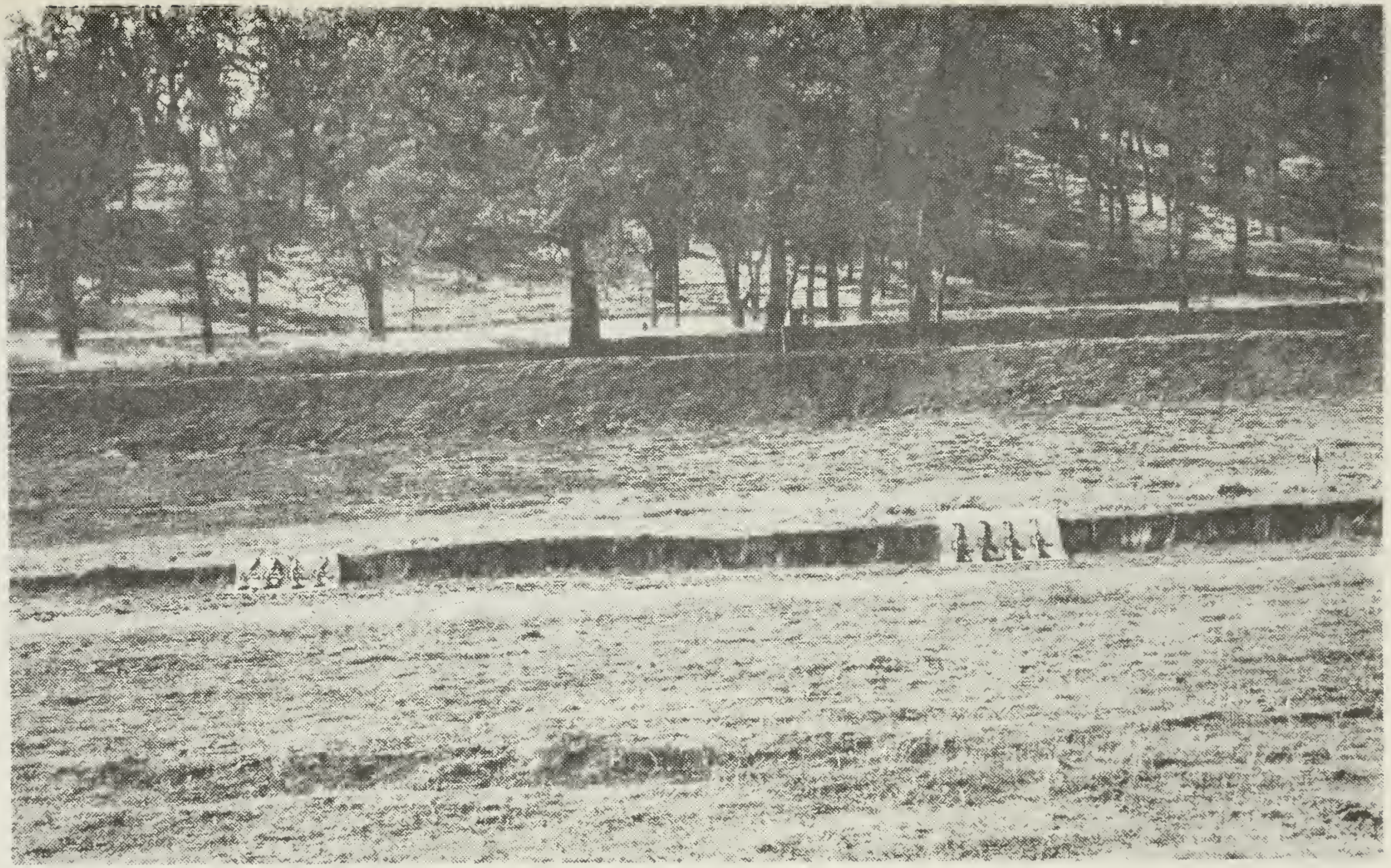

FIGURE 7. Target as Viewed from the 50 Yard Range by the Firer

picture are the right and left firing points at the 25 yard (22.86 m.) firing line. The berm that protected the track and target cart can be seen beyond the firing line. The track, target cart, raised target, and berm are shown in Figure 8.

The target was a polyethylene, kneeling (E-type) silhouette that was 30 inches (76.2 cm.) wide and presented a vertical height of approximately 30 inches (76.2 cm.) above the berm when in a raised position (Figure 9). It was mounted on a modified Army, M13A1 target mechanism which was, in turn, mounted on a cart. Two on-board batteries provided the power to raise and lower the target. An electronics package mounted on the cart provided remote operation of the target mechanism and the sensing of hits. Motive power for the cart was provided by an industrial Volkswagen engine through a hydraulic clutch mechanism and cables on two take-up reels that permitted the cart to run in both directions at controlled speeds. Start-up of the cart was rapid. The control panel had a tachometer and speedometer to permit control of the speed of the target. A cart-position, display panel of lights showed where the cart was in 25 feet (7.62 m.) segments of the track. The cart was run at a speed of six mph. (9.65 km/hr.) and the target was exposed for 2.5 seconds. The target dropped when it was hit during the 2.5 second interval. The moving target system was operated almost continuously for six hours on each of two test days and made over 700 passes. Only minor problems were encountered. The operators and standby maintenance and supervisory personnel were provided by CDEC's Instrumentation Division.

4.2.4. Experimental Design.

The experimental design was a repeated measures design with each S firing under all conditions. The independent variables were the three weapon

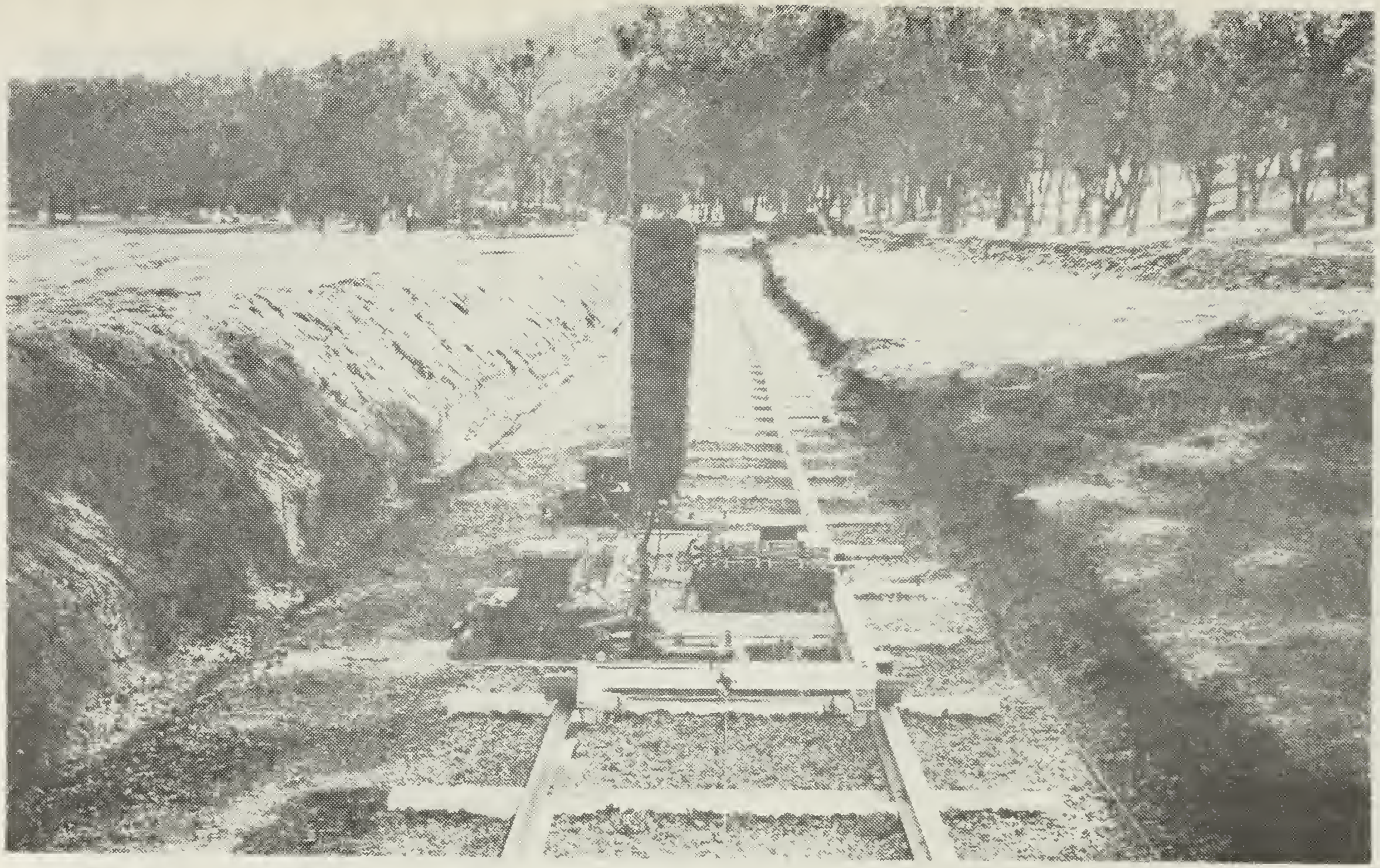

FIGURE 8. View of Track and Target Cart

FIGURE 9. Target as Viewed from 25 Yard Range by the Firer

configurations, the two ranges, direction of movement of the target, and the 12 Ss.

4.2.5. Procedure.

Prior to actual test firing, the Ss were given an orientation and familiarization firing. In the orientation, the Ss were informed of the problem under investigation, the procedures that would be followed in the test sequences, and the range safety procedures. They were given an explanation and weapons demonstration on the techniques they would use for standard quick-fire and quick-fire with the modified sight configurations. The Ss then fired five rounds at a stationary target from 25 yards (22.86 m.) to refresh their memory on firing procedures and to permit correction of discrepancies. The target was then allowed to move at 6 mph. (9.65 km/hr.), and each S fired 10 rounds to learn to engage the moving target successfully using quick-fire. Following these procedures, each S fired half of the test sequence for familiarization and to eliminate learning effects in the actual test. A half-sequence was created by having one-half of the Ss fire from the right position at 25 yards (22.86 m.) and from the left position at 50 yards (45.72 m.); the other half of the Ss fired the remaining positions.

The actual test firing was constrained by several considerations that were time and equipment related. Essentially, it was necessary to run the target from one side to the other and then back again. On each run of the round trip, the target had to be engaged. This was the most economic use of the system. This meant that the S knew from which direction the target would be approaching but not when it would appear. Time constraints also dictated that all firing be completed at the 25 yard (22.86 m.) range before firing at the 50 yard (45.72 m.) range. Ideally, the S should not have been aware of

the direction of approach of the target, and assignment of firing orders to the four firing positions should have been random.

The actual test procedure adopted had the Ss firing in a random order with respect to sight configuration, firing position, and order of firing at each range. The S assigned to the left position fired one round at the target on its left-to-right run, and the firer at the right position fired one round at the target on its return run from right-to-left. Each S fired at five target presentations from any one position with a particular sight configuration. Accordingly, he fired a total of 60 record runs for the four positions and three sight configurations. There were 720 data points in total for the experiment. The dependent measure was the number of targets hit by one S at each firing position with each weapon configuration.

4.2.6. Results.

The overall results of the experiment are shown in Table 2. The overall hit rate was 51.5 percent with a hit rate of 66.7 percent at 25 yards (22.86 m.) and 36.4 percent at 50 yards (45.72 m.). Over the entire experiment, the small bracketing sight attained a hit rate of 63.3 percent; the large bracketing sight, a hit rate of 65.8 percent; and the standard sight and quick-fire technique, a hit rate of 25.4 percent. As previously, the data in Table 2 were subjected to a four-factorial, randomized blocks design, analysis of variance with the Ss considered as blocks. Again, the data were normalized using the arcsin transformation. The only significant effects were those for sights, $F\ (2, 22) = 40.53$, $p < .001$, and for range, $F\ (1,22) = 46.38$, $p < .001$. The maineffect for direction of target movement was not significant. None of the interactions of the main effects was significant. A Scheffé multiple comparison test for the sight variable showed both the small and large bracketing

(a) 25 Yards (22.86 m.)

Sights	Direction Right	Direction Left	Total
Small	50 (83.0)	47 (78.3)	97 (80.8)
Large	48 (80.0)	50 (83.0)	98 (81.7)
Standard	25 (41.7)	20 (33.3)	45 (37.5)
Total	123 (68.3)	117 (65.0)	240 (66.7)

(b) 50 Yards (45.72 m.)

Sights	Direction Right	Direction Left	Total
Small	27 (45.0)	28 (46.7)	55 (45.8)
Large	27 (45.0)	33 (55.0)	60 (50.0)
Standard	10 (16.7)	6 (10.0)	16 (13.3)
Total	64 (35.5)	67 (37.2)	131 (36.4)

(c) Both Ranges

Sights	Direction Right	Direction Left	Total
Small	77 (64.2)	75 (62.5)	152 (63.3)
Large	75 (62.5)	83 (69.2)	158 (65.8)
Standard	35 (29.2)	26 (21.7)	61 (25.4)
Total	187 (51.9)	184 (51.1)	371 (51.5)

TABLE 2.

RESULTS OF THE MOVING TARGET EXPERIMENT

(Hits, above, and percent hits, below, in parentheses)

sights to be better than the standard sight with no difference between the two experimental sights.

4.2.7. Discussion.

Table 3 shows the percent improvement attained over the standard procedure in firing at moving targets when the bracketing sights are used. Statistically, it was shown that these differences are highly significant. As in the preceding experiment, the deterioration of fire at the greater range is severe, but the deterioration is greatly ameliorated with the use of the bracketing-sight principle. Another way of saying the same thing is that the aid provided by the bracketing sights is, again, greater when the firing situation is more difficult. In the experiment with stationary targets, the small sight was better by 29 percent at 25 yards (22.86 m.) and by 31 percent at 50 yards (45.72 m.). The aid provided at the greater range was 63 percent more than at the shorter range [(31-19)/19]. In this experiment aid provided by the large sight at 50 yards (45.72 m.) was 275 percent and at 25 yards (22.86 m.), 118 percent over the hit percent under the standard configuration. The aid provided at the greater range is 133 percent more than at the shorter range [(275-118)/118]. Another observation to be made of the results is that the hit rate was approximately one-third better at 50 yards (45.72 m.) using the bracketing sights than the hit rate at 25 yards (22.86 m.) using the standard configuration and quick-fire technique. A final point to note is that, while the differences were not statistically reliable, the large bracketing sight was at least equal to the small bracketing sight and probably better. This was suggested as one of the possible findings that the moving-target might reveal.

The questionnaire results again showed that the firers felt that the bracketing sights provided an advantage over the standard technique. They still

Sight Configuration	Range		Combined
	25 yds (22.86 m.)	50 yds (45.72 m.)	
small circle	115.0 %	244.0 %	149.0 %
large circle	118.0 %	275.0 %	159.0 %

TABLE 3.

Percent Improvement Using Bracketing Sights
Over the Standard Sight Configuration
For Moving Targets.

preferred the small sight over the large sight by a margin of 9-to-3, even though they seemed to do better with the larger sight. The significance of this statement, beyond its obvious content, is that the firing results are not just a reflection of the firer's preferences.

5. Concluding Remarks.

5.1. Overall Results.

There can be little doubt that the bracketing sights provided a significant improvement over the standard configuration and accepted quick-fire technique. One reason why they proved to be of such a significant aid might be because the standard, quick-fire techniques are very poor. But the fact that the bracketing sights provided even greater advantages as the firing became more difficult implies that they have an absolute, beneficial effect of their own. This means that the concept should be further explored to determine the target and situational parameters that are sensitive to variations in the size, shape, location, and other configurations of the bracketing sight. When these relationships are known, it would be possible to design and optimize a sight that would greatly enhance short-range, quick-reaction fire using small arms.

5.2. Training Implications.

The experiments showed that proficiency in using the bracketing sights was easily established. They were meant to be most compatible with the natural reactions and capabilities of the user, and, indeed, the results bore this out. The inference can be made from these findings that the bracketing sight would be most useful in training neophyte firers to acquire and engage fleeting or moving targets. In fact, appropriately sized, they could be a useful training aid in learning to fire at a stationary, fixed target. Experimentation in an actual training situation could confirm and delineate the ways in which the bracketing sight could prove most helpful in training.

5.3. Other Applications.

The bracketing sight should be especially effective when an individual fires multiple missiles against the target that result in a distribution of hits or shot group. This type of fire would occur with automatic fire and with shotguns or riot guns. The problem with automatic fire is keeping the weapon on the target as recoil forces work against the body and tend to dislodge the line of sight. The bracketing sight would serve to help recapture the target when this happens much more readily than the standard sights. With the riot gun, the problem is not so much in attaining hits but in preventing unwanted hits. With 00 buckshot, the spread and lethal range of the pellets is not fully appreciated until, as demonstrated in two school disturbances in the South, fatalities occur that stun and surprise those who perpetrate them. The bracketing sight, appropriately sized, could help to prevent such unfortunate incidents by showing the firer all potential targets in the cone of fire. In both cases, automatic fire and employment of the riot gun, the efficiency of the fire with respect to the intended target would be greatly improved. These ideas could also be applied to machineguns and to fire, semiautomatic or automatic, from moving vehicles such as the newer designs contemplated for personnel carriers and from airborne platforms, such as helicopters.

5.4. Qualifications.

The findings in this study are a function of the fixed parameters that were used. Especially important in this respect were the duration for target exposures and the speed of the moving target. These had to be established in preliminary experimentation to provide a range of hit probabilities that would be useful in evaluating the weapon configurations. Essentially, this meant that hit probabilities would have to be high enough using the standard

configuration and procedure to permit the bracketing sights to be better or worse. As it turned out, overall, single-shot, hit probabilities were near 50 percent in the two experiments, where the variance is the greatest for data that are collected as proportions. This permitted a good separation of relative differences among the sight configurations. Obviously, if the targets were impossible to hit or so easy to hit that misses were infrequent, no differences could have been demonstrated.

5.5. Methodology.

Finally, it should be noted that a carefully conducted human activity analysis established the critical features that required aiding to improve pointing fire. The steps used in this study to analyze the problem, develop solutions, and field test the resulting man-machine system in a realistic setting could be applied to any problem where there is the need to improve the man-machine relationship. The military environment happens to provide many problems of this nature, but the law-enforcement environment should also provide its share of such problems that could benefit from the application of these procedures.

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